Announcements

- Homework for tomorrow…

  Ch. 32: CQ 7, Probs. 16, 18, & 48

  32.4: a) $-(3.2 \times 10^{-15}$ T) jhat b) 0 T c) $+(1.1 \times 10^{-15}$ T) ihat

  32.6: $+(2.9 \times 10^{-16}$ T) khat

  32.7: $(6.3 \times 10^{6}$ m/s) khat

- Office hours…

  MW 10-11 am

  TR 9-10 am

  F 12-1 pm

- Tutorial Learning Center (TLC) hours:

  MTWR 8-6 pm

  F 8-11 am, 2-5 pm

  Su 1-5 pm

Chapter 32

The Magnetic Field

(*Magnetic Dipoles & The Magnetic Force on a Moving Charge*)

Review…

The B-field of an *long wire* carrying a current I a distance d from the wire…

$$B_{wire} = \frac{\mu_0 I}{2\pi d}$$

The B-field of a *current loop* of radius R carrying a current I…

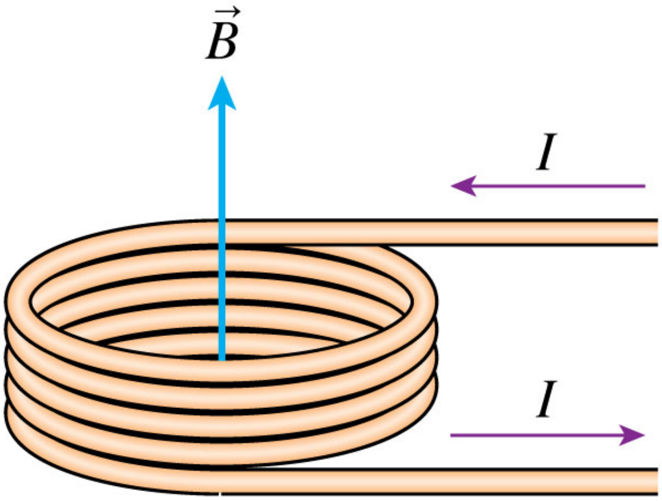
$$B_{loop} = \frac{\mu_0}{2}\frac{IR^2}{(z^2+R^2)^{3/2}}$$

The B-field of a *coil* consisting of N turns of wire..

$$B_{coil\ center} = \frac{\mu_0}{2}\frac{NI}{R}$$

i.e. 32.6: Matching the earth's B-field

What current is needed in a 5-turn, 10 cm diameter coil to cancel the earth's magnetic field at the center of the coil?



$B_{earth} = 5.0 \times 10^{-5}\,T$

$R = 5.0 \times 10^{-2}\,m$

$N = 5$

$B = 5.0 \times 10^{-5}\,T$

$\mu_0 = 4\pi \times 10^{-7}\,Tm/A$

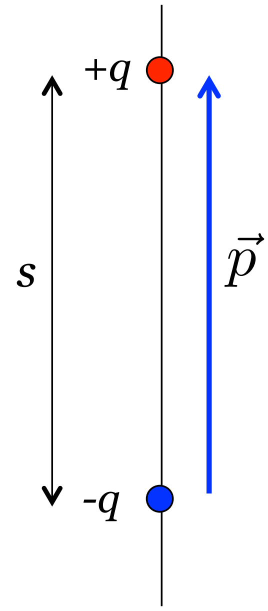
$$B = \frac{\mu_0 N I}{2R}$$

$$\frac{2RB}{\mu_0 N} = I \qquad I = \frac{5}{2\pi}A = 0.80A$$

Electric dipole moment, revisited…

- Electric dipole moment

$$\vec{p} = q s, \text{ from the - to + charge}$$



- *E-field* of a dipole on the *dipole axis*

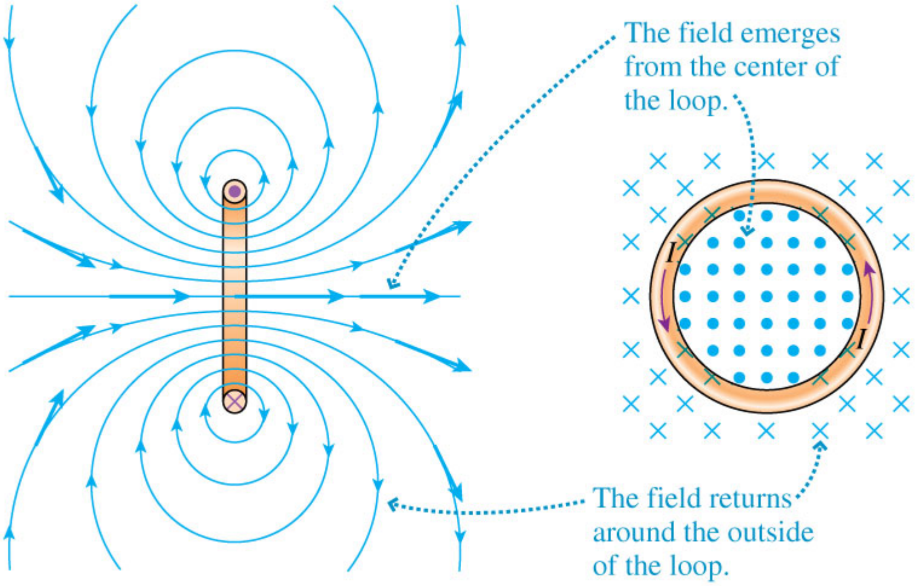
$$\vec{E}_{dipole} = \frac{1}{4\pi\epsilon_0}\frac{2\vec{p}}{z^3}$$
on the axis of the electric dipole

Notice:

- *z* is distance measured from the *center* of dipole.
- *z* >> *s*

32.5: Magnetic Dipoles

The *B*-field of a current loop…



Notice:
This field has *rotational* symmetry

32.5: Magnetic Dipoles

The *B*-field of a *magnetic dipole moment* is...

On Axis Current Loop is ....

$$B_{loop} = \frac{\mu_0}{2}\frac{IR^2}{(z^2+R^2)^{3/2}}$$

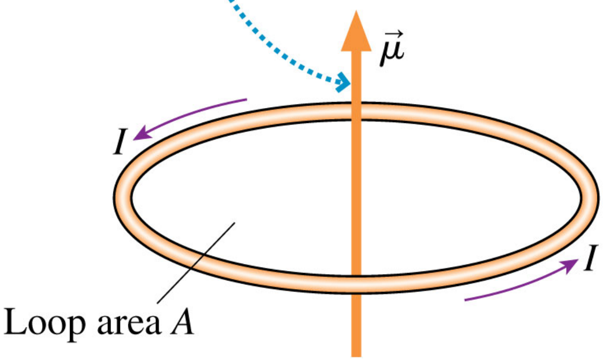
$$\vec{B} = \frac{\mu_0}{2}\frac{IR^2}{z^3}\cdot\frac{2\pi}{2\pi} = \frac{\mu_0}{4\pi}\frac{2(\pi R^2)I}{z^3}$$

$$\vec{B} = \frac{\mu_0}{4\pi}\frac{2AI}{z^3}$$

$\vec{\mu} = IA$, From South to north

$$\lim_{z \gg R} \vec{B}_{loop} = \vec{B}_{Dipole} = \frac{\mu_0}{4\pi}\frac{2\vec{\mu}}{z^3}$$

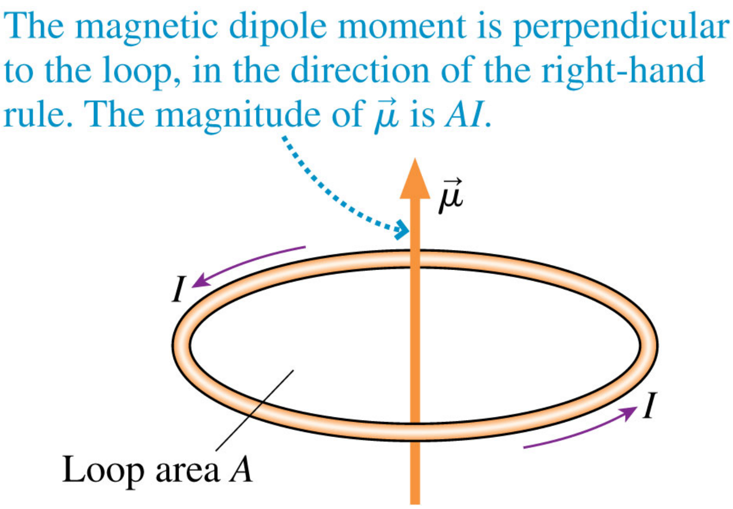
The magnetic dipole moment is perpendicular to the loop, in the direction of the right-hand rule. The magnitude of $\vec{\mu}$ is AI.



32.5: Magnetic Dipoles

The *B*-field of a *magnetic dipole moment* is...

$$\vec{B}_{dipole} = \frac{\mu_0}{4\pi}\frac{2\vec{\mu}}{z^3}$$



Notice:

This result is valid *on axis* of dipole, when $z >> R$!

where

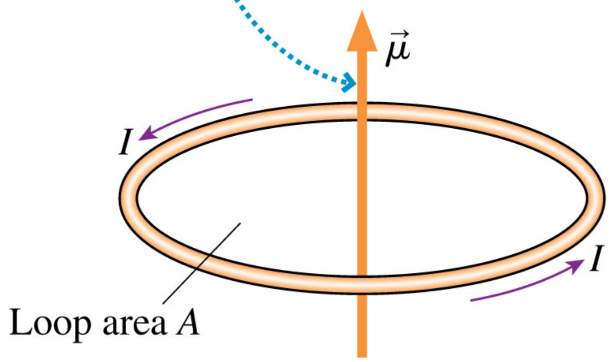
$$\vec{\mu} = (AI, \text{from the south to north pole})$$

Comparing the Electric dipole moment to Magnetic dipole moment…

The *B*-field of a *magnetic dipole moment* is…

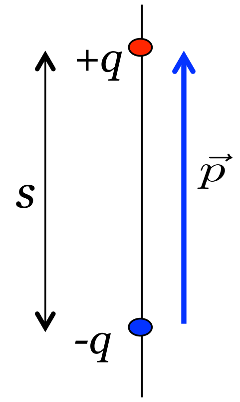
$$\vec{B}_{dipole} = \frac{\mu_0}{4\pi}\frac{2\vec{\mu}}{z^3}$$

The magnetic dipole moment is perpendicular to the loop, in the direction of the right-hand rule. The magnitude of $\vec{\mu}$ is AI.



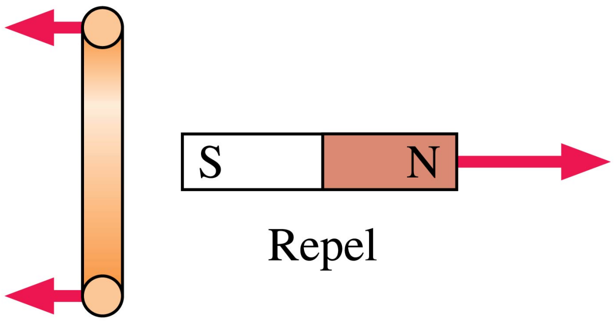
The E-field of an *electric dipole moment* is…

$$\vec{E}_{dipole} = \frac{1}{4\pi\epsilon_0}\frac{2\vec{p}}{z^3}$$



Quiz Question 1

What is the current direction in the loop?

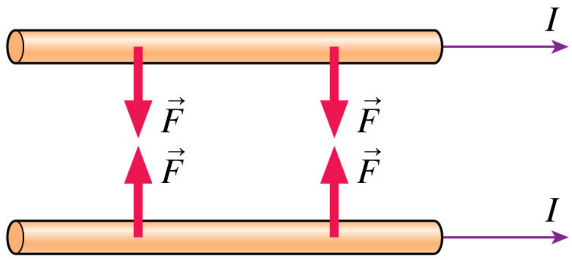


1. Out at the top, in at the bottom.
2. In at the top, out at the bottom.
3. Either 1. or 2. would cause the current loop and the bar magnet to repel each other.

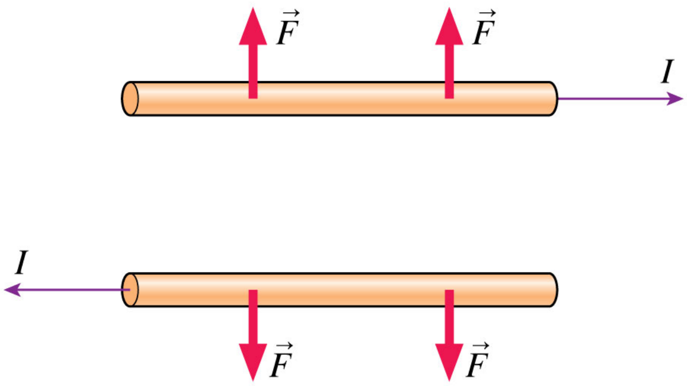
32.7:
The Magnetic Force on a Moving Charge

- After the discovery that electric currents produce *B*-fields, Ampère set up two parallel wires that could carry large currents either in the *same or opposite* direction.

- Ampère's experiment showed that a *magnetic field* exerts a *force* on a current!



"Like" currents attract.

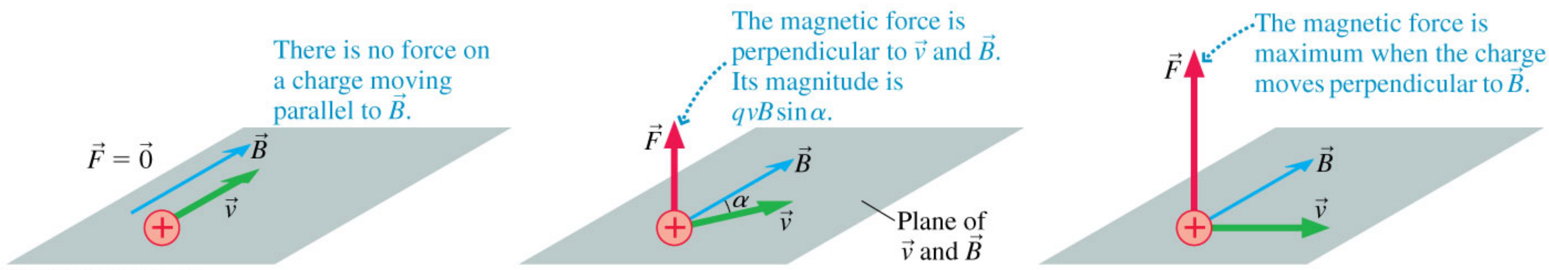


"Opposite" currents repel.

The Magnetic Force on a Moving Charge

Ampere's experiment implied that...

a B-field exerts a force on a *moving charge*!



$$\boxed{\vec{F}_{on\ q} = q\vec{v} \times \vec{B}}$$

Magnitude:

$$F_{on\ q} = qvB\sin\alpha$$

Direction:

given by *RHR*

The Magnetic Force on a Moving Charge

Several important properties:

1. *Only* a *moving charge* experiences a *magnetic force*.
2. There is NO *magnetic force* on a charge moving parallel/ antiparallel to a *B*-field.
3. When there is a force, the force *is perpendicular* to *v* & *B*
4. The force on a *negative* charge is in the direction *opposite* to

$$\vec{v} \times \vec{B}$$

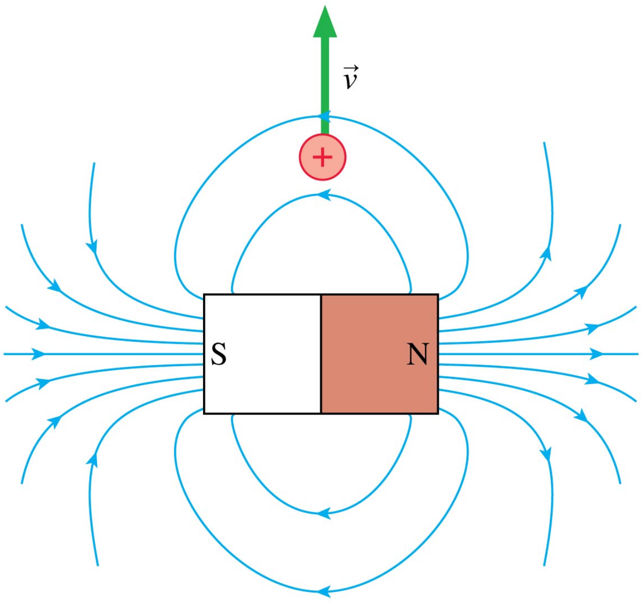
5. For a charge moving *perpendicular* to *B*, the *magnitude* of the *magnetic force* is

$$F = |q|vB$$

$$\boxed{\vec{F}_{on\ q} = q\vec{v} \times \vec{B}}$$

Quiz Question 2

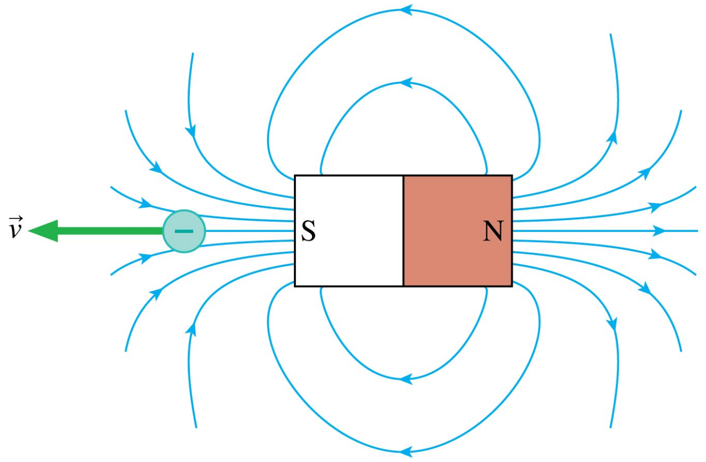
The direction of the magnetic force on the proton is



1. to the right.
2. to the left.
3. into the screen.
4. out of the screen.
5. The magnetic force is zero.

Quiz Question 3

The direction of the magnetic force on the electron is

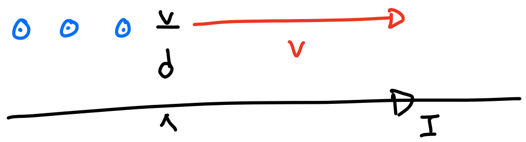


1. upward.
2. downward.
3. into the screen.
4. out of the screen.
5. The magnetic force is zero.

i.e. 32.10: The magnetic force on an electron

A long wire carries a 10 A current from left to right. An electron 1.0 cm above the wire is traveling to the right at a speed of 1.0 x 10^7 m/s.

What are the magnitude and the direction of the magnetic force on the electron?



$I = 10A$

$V = 1.0 \times 10^7 m/s$

$d = 1.0 \times 10^{-2} m$